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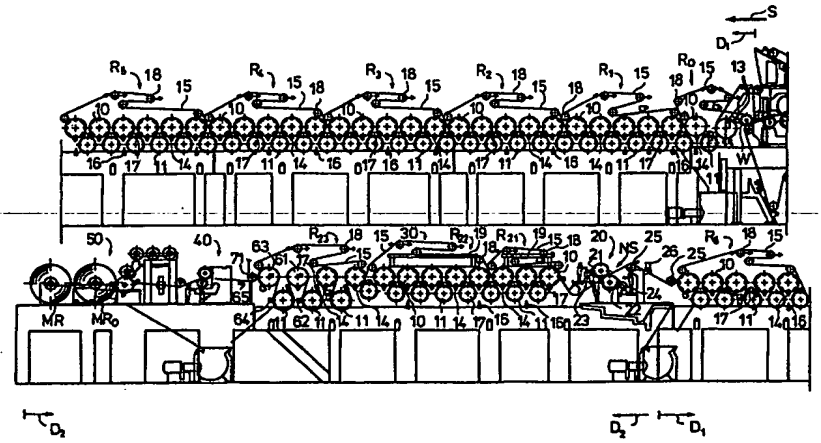

(57) Abstract

The invention concerns a method in the dryer section of a paper or board machine for control of the curl of paper, in which method steam treatment and/or moistening of the paper web (W) is/are employed. In the method, the operations carried out in view of controlling the curl of the paper web (W) are carried out in a number of stages and/or when the web (W) temperature is lower than 85 °C, preferably lower than 75 °C, and/or when the dry solids content of the web (W) is in the range of K1...K2, wherein K1 = ultimate dry solids content – 7 % and K2 = ultimate dry solids content + 3 %. Further, the invention concerns a paper or board machine, which comprises at least a headbox, a former, a press, and a dryer section, in which steam boxes or moistening devices are employed for control of the curl. There are at least two of said curl regulation devices in view of achieving a regulation of the curl in a number of stages, and/or said curl regulation devices have been fitted to operate in an area in which the web temperature is lower than 85 °C, preferably lower than 75 °C, and/or the dry solids content of the web is in a range of K1...K2, wherein K1 = ultimate dry solids content – 7 % and K2 = ultimate dry solids content + 3 %.

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Method for control of the curl of paper in the dryer section of a paper machine and paper or board machine

The invention concerns a method in the dryer section of a paper or board machine for control of the curl of paper, in which method steam treatment and/or moistening of the paper web is/are employed.

The invention also concerns a paper or board machine, which comprises at least a headbox, a former, a press, and a dryer section, in which steam boxes or moistening devices are employed for control of the curl.

As is known from the prior art, in multi-cylinder dryers of paper machines, twin-wire draw and/or single-wire draw is/are employed. In twin-wire draw the groups of drying cylinders comprise two wires, which press the web one from above and the other one from below against heated cylinder faces. Between the rows of drying cylinders, which are usually horizontal rows, the web has free and unsupported draws, which are susceptible of fluttering, which may cause web breaks, in particular so when the web is still relatively moist and, therefore, of low strength. This is why, in recent years, ever increasing use has been made of said single-wire draw, in which each group of drying cylinders includes just one drying wire, on whose support the web runs through the whole group so that the drying wire presses the web on the drying cylinders against the heated cylinder faces, whereas on the reversing cylinders or rolls between the drying cylinders the web remains at the side of the outside curve. Thus, in single-wire draw, the drying cylinders are placed outside the wire loop, and the reversing cylinders or rolls inside said loop.

From experience it is known that, if paper is dried one-sidedly, the result is a tendency of curling of the sheet. When paper is dried by means of normal groups with single-wire draw from the side of its bottom face and if such asymmetric drying

is extended over the entire length of the forward dryer section, the drying takes place so that first the bottom-face side of the paper web is dried and, when the drying makes progress, the drying effect is also extended to the side of the top face of the paper web. Under these circumstances, the dried paper is usually curled and becomes concave, seen from above.

As is known from the prior art, the tendency of curling of paper is already affected in connection with the web formation, in particular at the sheet formation stage (for example, the applicant's **Sym-Former™**) by means of selection of the difference in speed between the slice jet and the wire, by means of the choice of the former and its mode of running, and by means of other running parameters. As is known from the prior art, for example, in the case of copying paper, by means of unequalsidedness of drying in the after-dryer a suitable initial curl form is regulated for the sheet in order that the curling of the paper after one-sided or double-sided copying could be optimized. In the case of copying paper, the reactivity of curling, i.e. the extent to which curling occurs per unit of change in moisture content, is affected to a greater extent by means of a multi-layer structure of the paper, which is produced in connection with the web formation in the wet end.

The most recent prior-art technology related to the present invention in high-speed paper machines has been based on dryer sections in which there is single-wire draw over the major part of the length of the dryer section, and in view of controlling the tendency of curling, an inverted group has also been used in order that the drying could be made sufficiently symmetric in the z-direction. However, it has come out that an inverted group produces obvious drawbacks in view of the runnability and the overall efficiency of the machine and in view of the profitability of the paper machine investment. Thus, from the point of view of the runnability of the paper machine, a dryer section fully supported over its entire length and based on normal groups with single-wire draw with no inverted groups would be a particularly justified solution. People skilled in the art have, however, not had the courage to introduce this solution in operation, because it has been considered that it would result in solutions uncontrollable and unfavourable from the point of view of the

tendency of curling of paper. One problem involved in the prior-art solutions that include inverted dryer groups is the removal of broke in the event of web breaks, for inverted groups are not self-cleaning by the effect of gravity.

Thus, the object of the present invention is to provide a dry end of a paper machine in which no inverted groups are needed at all, but which, however, meets all other requirements that are imposed.

Thus, the object of the present invention is to approach these problems from a new point of view and to suggest novel solutions for said problems, which solutions are contrary to conventional modes of thinking.

With respect to the prior art related to the present invention, reference is made to the applicant's *FI Patent No. 91,900 (equivalent to US Pat. No. 5,416,980)*, in which a method is described in the dryer section of a paper machine in particular for reducing the tendency of curling of paper, in which method the paper web is dried by means of drying cylinders, against whose heated faces the paper web is pressed by means of a drying wire, and in which dryer section groups of drying cylinders are used in which twin-wire draw and/or single-wire draw is/are applied. In this method it has been considered novel that in the dryer section, substantially across the entire width of the paper web, hot water steam is fed, by whose means the strains that arise or tend to arise in the fibre mesh in the paper web are relaxed by means of heat and moisture in, or substantially directly after, the area of formation of said strains.

In the applicant's *FI Patent Application No. 963734 (equivalent to provisional US Patent Application No. 60/030,693)* a method is described for drying a surface-treated paper web or equivalent in an after-dryer of a paper machine, as well as an after-dryer for a paper machine for applying the method, wherein, in order to compensate for a tendency of curling of the paper web, in the after-dryer the paper web is dried in a dryer group/groups making use of a normal single-wire draw, and that, in connection with or after the drying, the paper web is treated by means of a

device/devices in order to compensate for a tendency of curling of the paper web, which devices are, for example, a steam box, a blow unit, a moistening device, and/or a soft calender.

On the other hand, in the applicant's *FI Laid-Open Publication No. 98,387 (equivalent to US Patent Application No. 08/705,059)*, a method is described for the manufacture of paper, in particular fine paper, to be surface-treated as well as a dry end of a paper machine that makes use of the method. The paper web, which has been dewatered by pressing, is dried in a forward dryer section, in which drying energy is applied to the paper web over the entire length of the forward dryer section asymmetrically in the z-direction from the side of the lower face of the web. Said stage is carried out by means of a number of successive groups with single-wire draw open towards the bottom on the support of the drying wire. In this way, shrinkage of the web, which tends to take place both in the machine direction and in the cross direction with an increase in the dry solids content, is substantially prevented. In connection with a web break, the paper broke is removed downwards from the dryer groups open towards the bottom substantially by the force of gravity onto the broke conveyor placed underneath. Owing to the asymmetric forward drying, the paper web with a tendency of curling is passed into a finishing section, in which it is after-treated while it is, at the same time, moistened or worked plastically so that the tendency of curling that arose in it in the forward drying stage is eliminated. As examples can be mentioned, in the after-dryer section, groups with twin-wire draw and regulation of steam as well as the steam boxes fitted to control the curl as well as the infra and airborne web drying.

In the applicant's *FI Patent Application No. 964830 (equivalent to provisional US Patent Application No. 60/032,405)*, a method is described for drying of paper as well as a dry end of a paper machine. The method for drying of paper comprises the following steps: the paper web to be dried is passed from the press section into a forward dryer section, in which the paper web is dried from the side of its bottom face in dryer groups that apply a normal single-wire draw, said forward dryer section comprising exclusively single-wire groups with normal single-wire draw, and

from the forward dryer section the paper web is passed into a finishing section, in which the paper web is coated/surface-sized by means of a coating/surface-sizing equipment, dried in an after-dryer section, in which the paper web is dried in at least one dryer group that applies a normal single-wire draw, after which the paper web is calendered in a calender and passed to a reeling station, in which the paper web is reeled into a machine reel, and in the method the curling of the paper web is controlled by means of elements and/or by means of assemblies and combinations formed out of said elements in the area of the forward dryer section and/or of the finishing section. On the other hand, the dry end of the paper machine comprises a forward dryer section and a finishing section, which finishing section comprises a coating/surface-sizing equipment, an after-dryer, a calender, and a reeling station. The dry end of the paper machine comprises elements and/or assemblies and combinations formed out of said elements in view of controlling the curling of the paper web in the area of the forward dryer section and/or of the finishing section. The elements for the control of the curl include, among other things, blowing of hot moist air through the wire in the forward dryer section, steam boxes employed in the after-dryer, a combination in which steam treatment by means of a steam box is combined with a cooling cylinder, a lower support belt or support wire in the after-dryer, twin-wire groups employed in the after-dryer, blowing through the wire in connection with at least one cylinder in the after-dryer, the use of a suitable cylinder-diameter ratio, atomizing of water against the web in the after-dryer, infrared boxes for treatment of the web before the calender, transfer of moist air from the forward dryer to the after-dryer to be blown against the web, and mechanical working of the web by means of a spreader bar.

With respect to the prior art, reference is also made to the *US Patent 5,557,860*, in which a dryer section is described which is composed of dryer groups with a normal single-wire draw and of a moistening device fitted after the dryer groups, by means of which moistening device the curl is controlled.

The object of the present invention is further development of the prior-art solutions described above in order that it should be possible to control the curl of the paper web in the dry end of the paper machine more efficiently.

It is a further object of the present invention to provide a dry end of a paper machine with finishing devices in which the runnability can be brought to a particularly high level.

In view of achieving the objectives stated above and those that will come out later, the method in accordance with the invention is mainly characterized in that, in the method, the operations carried out in view of controlling the curl of the paper web are carried out in a number of stages before the finishing device that works the web mechanically in a dry solids content range K1...K2 of the web, wherein K1 = ultimate dry solids content - 7 % and K2 = ultimate dry solids content + 3 %, and when the web temperature is, during at least one stage, lower than 85 °C, preferably lower than 75 °C.

The paper or board machine in accordance with the invention is characterized in that there are at least two of said curl regulation devices in view of achieving a regulation of the curl in a number of stages, and that the operations carried out in view of controlling the curl of the paper web are carried out in a number of stages before the finishing device that works the web mechanically in a dry solids content range K1...K2 of the web, wherein K1 = ultimate dry solids content - 7 % and K2 = ultimate dry solids content + 3 %, and when the web temperature is, during at least one stage, lower than 85 °C, preferably lower than 75 °C.

According to the invention, the curl is regulated when the web temperature is lower than 85 °C, preferably lower than 75 °C. Steam condenses into the web more efficiently when the web temperature has been lowered to a level below 85 °C, preferably below 75 °C. In relation to this the applicant of the patent has carried out experiments with a production machine. When the last upper cylinder in the dryer section was hot, a steam box placed directly after said cylinder had no major effect

on the curl; when the supply of steam into said cylinder was closed, the temperature of the web became lower, and a significant effect was produced by the steam box.

According to the invention, the curl of the paper web is regulated in the final end of the drying process. The applicant has also noticed that an excessive drying promotes the control of the curl when moistening/steam treatment is employed. According to the invention, optimal controllability is obtained in a range of dry solids content that extends from about 7 % lower than the desired ultimate dry solids content to about 3 % above said content. In the case of surface-sized fine paper, said range is typically 88 % to 98 %.

Further, according to the invention, the curl regulation operations, such as steam treatment/moistening and cooling of the web, are carried out in a number of stages, in which case a highly efficient curl regulation effect is obtained. This comes out from the accompanying Fig. 3, from whose test results it comes out that a web that has been dried from one side only is curled intensively (20 units). A mere steam treatment in one stage reduces the curl substantially, but the web is still curled in the original direction by about 5 units. When the web has been moistened slightly before the steam treatment, the web curl direction can be even reversed.

A moistening device is highly efficient in lowering the web temperature. In some applications, e.g., a cooling cylinder can be substituted for by a moistening device.

In an arrangement in accordance with the present invention, the dry end of the paper machine is preferably exclusively based on dryer groups with single-wire draw, in which case the removal of broke takes place constantly by the force of gravity and does, thus, not cause problems. Likewise, in single-wire draw, the paper web is constantly supported by a wire, in which case the runnability is improved and it is possible to increase the speed. In view of controlling the unequalsidedness of paper and in particular the curl arising from unequalsided drying, in the after-dryer in the dry end of the paper machine elements have been provided for the control of the

tendency of curling in accordance with the principles described above so that the desired curl is obtained for the paper.

According to an exemplifying embodiment of the invention, in the after-dryer, for the control of the curl, cylinders which can be cooled and/or whose temperature can be regulated as well as moistening or steam boxes are used, which have been placed alternatingly so as to provide a multi-stage cooling/moistening-curl cycle, together with an optimal roll/cylinder diameter as a combination formed in a favourable way. In prior-art arrangements, it is affected by means of optimization of the cylinder-roll diameter ratio that when the diameter of a suction roll is made larger, the evaporation taking place through the lower face is increased, and the other way round. A favourable feature of the invention is the choice of a suitable cylinder-roll diameter ratio so that, when the web runs around a suction roll or equivalent of larger diameter, the web temperature is lowered. After this, for example, a steam box is fitted so as to provide moistening in view of regulation of the curl.

The paper web is preferably also cooled primarily from the bottom side when the forward dryer and the after-dryer in the dryer section are, as a rule, provided with a normal single-wire draw, i.e., in principle, attempts are made to produce a temperature gradient in the paper web so that the side that is moistened for control of the curl is colder than the opposite side of the web.

In the following, the invention will be described in more detail with reference to the figures in the accompanying drawing, the invention being, however, by no means supposed to be strictly confined to the details of said illustrations.

Figure 1 is a schematic illustration of an exemplifying embodiment of the present invention in respect of the dry end of a paper machine, the dry end of the paper machine being illustrated from the forward dryer section up to the machine reel.

Figure 2 is a schematic illustration in part of Fig. 1, mainly in respect of the last dryer group in the after-dryer of the finishing section in the dry end of the paper machine.

Figure 3 is a schematic illustration of test results in relation to regulation of the curl in paper by means of water moistening and steam treatment.

As is shown in Fig. 1, the paper web W is brought to the forward dryer section D1 from the press section onto the drying wire 15 of the first group R_0 with single-wire draw, to which wire the web is made to adhere by the effect of the vacuum in the suction boxes 13. The forward dryer section includes 7 groups $R_0...R_6$ with single-wire draw, over whose group gaps the web W has a closed draw. In the figures, the machine direction, i.e. the running direction of the web W, is denoted with the arrow S. In the forward dryer section D1 in accordance with the invention, all the single-wire groups $R_0...R_N$ are so-called normal groups, in which the, for example, steam-heated smooth-faced drying cylinders 10 are placed in the upper horizontal row and the reversing suction cylinders 11 are placed in the lower horizontal row. The number of dryer groups $R_{0...N}$ is, as a rule, N = 4...12, preferably 6...8.

Each normal group $R_0...R_N$ has a drying wire 15 of its own, which is guided by guide rolls 18. The drying wires 15 press the web W to be dried on the drying cylinders 10 against the smooth heated faces of the cylinders, and on the reversing cylinders 11 the web W remains at the side of the outside curve on the outer face of the wire 15. On the reversing cylinders 11 the web W is kept reliably on the support of the wire 15 against the effects of centrifugal forces by the effect of the vacuum present in the grooved faces of the reversing cylinders 11 or in the perforated mantles of equivalent suction rolls, by which means cross-direction shrinkage of the web W is also counteracted. As the reversing suction cylinders 11, particularly advantageously the suction cylinders marketed by the applicant with the **trade mark VacRoll™** are used, which cylinders have no inside suction boxes and in respect of the details of whose constructions reference is made to the *applicant's FI Patent No. 83,680 (equivalent to US Patents Nos. 5,022,163 and 5,172,491).*

In a forward dryer D1 in accordance with a preferred embodiment of the invention, the support contact between the web W and the drying wire 15 is kept adequate also on the straight draws between the drying cylinders 10 and the reversing cylinders 11 by, at least on the runs from the drying cylinders 10 to the reversing cylinders 11, making use of blow-suction boxes 17, by means of which boxes formation of pressures induced by the wire 15 is also prevented in the closing wedge-shaped nip spaces between the wire 15 and the cylinder 11 mantles. Blow-suction boxes 17 are understood as blow boxes whose air blowing produces a vacuum, and said boxes 17 do not communicate with sources of vacuum. With respect to the details of the constructions of these blow-suction boxes 17, which are marketed by the applicant with the trade mark "UnoRun BlowBox"™, reference is made to the applicant's *FI Patents Nos. 59,637, 65,460 and 80,491* (equivalent to *US Patents Nos. 4,441,263, 4,516,330 and 4,905,380*. Blow-box solutions of other types, in themselves known, are also included in the scope of the overall concept of the present invention.

In the forward dryer section D1, in the single-wire groups $R_0...R_N$, blow boxes 16 are also employed in the gaps between the reversing cylinders 11, by means of which boxes 16 said gap spaces are air-conditioned and evaporation from the web W is promoted. The faces of the drying cylinders 10 are kept clean by doctors 14.

It is a further substantial advantage of the forward dryer section D1 used in the invention that in the groups $R_0...R_N$ with single-wire draw, which extend over the entire length of the dryer section, removal of broke by the effect of gravity can be applied, for the single-wire groups $R_0...R_N$ are open towards the bottom, so that the paper web W that becomes broke can be removed without any special arrangements onto the broke conveyor (not shown) placed in the basement spaces of the paper machine and on said conveyor further into the pulper or pulpers.

In view of prevention of cross-direction shrinkage of the web W, it is of particular importance that, in the forward dryer section D1, the web W is kept in reliable contact with the drying wires 15 all the time. This holding effect is produced on the reversing cylinders 11 by means of a vacuum present in the grooved mantle 12 or

equivalent on said cylinders and, on the straight runs between the cylinders 10 and the reversing cylinders 11, by means of pressure levels arranged by means of the blow-suction boxes 17 and partly also by means of the tension T of the web W in the machine direction, which tension produces a contact pressure $p_k = T/R$ (R = radius of the cylinders 11) between the web W and the wires 15.

As was stated above, as the reversing cylinders 11 in the forward dryer D1, favourably the applicant's Vac™ rolls are used. This vacuum effect is spread through the perforations on the reversing cylinders 11 onto the grooved mantle 12 so that the wedge-shaped nip spaces between the reversing cylinders 11 and the drying wire can also be evacuated efficiently, so that pressures cannot be induced into these wedge spaces, which pressures would attempt to separate the web W from the drying wire when the web W is placed outside. If suction rolls provided with inside suction boxes are used as the reversing cylinders 11 in the forward dryer section D1, the suction zone should preferably be extended over an area wider than the turning sector of the drying wire 15 and the web, so that the suction effect and the free flow of air can be extended into said wedge spaces, for the purposes mentioned above.

Besides the forward dryer section D1 described above, the dry end of a paper machine in accordance with the invention includes a finishing unit D2 placed after the forward dryer D1, which finishing unit includes a machine reel-up 50, for example a Pope-type reel-up. A machine reel that is being produced on-line by means of the reel-up 50 is denoted with the reference MR_0, and one complete machine reel is denoted with the reference MR. The web W is brought to the machine reel-up 50 through the calender 40 from an after-dryer 30, which is placed after the coating device 20 in the finishing section D_2.

As is shown in the figures, after the forward dryer section D1 the paper web W, which has been dried to a dry solids content of $k_2 \approx 96...99$ %, is passed over paper guide rolls 25 and over a measurement beam 26, which is placed between said guide rolls 25 and which measures the property profiles of the paper, into a coating device 20, which is, for example, a coating device marketed by the applicant with

the name SymSizer™. The coating device 20 includes two coating rolls 21 and 22 placed one opposite to the other, and size feed devices 23 and 24 are placed in connection with both of said rolls so that the paper web W is coated from both sides in the coating nip NS between the rolls 21 and 22. Owing to the water-containing coating agent, the web W is partly moistened in the coating nip NS from both sides. Then, the web W, which was dried in the forward dryer D1 asymmetrically from the side of its bottom face W and which has a tendency of curling, is treated into such a state that its internal strains are partly relaxed or at least substantially reduced.

In the exemplifying embodiment shown in Fig. 1, the after-dryer 30 in the finishing section D_2 is also exclusively composed of dryer groups R_{21},R_{22},R_{23} with single-wire draw. The last dryer group R_{23} in the after-dryer 30, in which group the curl control arrangements are fitted, will be described in more detail in relation to Fig. 2. The first two groups R_{21},R_{22}, which are provided with a possibility of impingement blowing 19, are basically similar to the dryer groups R_0...R_6 in the forward dryer D_1 , and the same reference numerals are used for corresponding parts.

As is shown in Fig. 2, the last dryer group R_{23} in the after-dryer first includes a drying cylinder 10 in the group gap and a following reversing roll or cylinder 11 and further a second drying cylinder 10 and a following reversing cylinder 11. After this there follows a cylinder 61 of adjustable temperature, preferably a cylinder that can be cooled. After this the web W is passed onto the reversing roll or cylinder 11 in the lower row and onto a second cylinder 63 of adjustable temperature, preferably a cooling cylinder. The drying wire is denoted with the reference numeral 15, and its guide rolls are denoted with the reference numeral 18, the runnability components with the reference numeral 17, and the doctors with the reference numeral 14, as is the case in Fig. 1. At the outlet side of the last two reversing rolls or cylinders 11 in the last dryer group R_{23} in the after-dryer 30, before the cylinders 61,63 of adjustable temperature, preferably a moistening device 62 and preferably a steam box 64 are placed. Both devices can, of course, be both moistening or steam treatment devices. The paper web W is moistened/steam-treated before the web W is passed onto the cylinders 61,63, which are, thus, preferably cooled cylinders. From

the latter cooling cylinder 63 the web W is passed past the steam box 65 of the guide roll 71 to the calender 40 and further to the reel-up 50.

In accordance with the present invention, by means of alternation of moistening/steam-treatment devices 62,64 and cooling of the web W by means of cooling cylinders 61,63, a regulation of the curl in several steps has been achieved, in which case it is highly efficient. At this stage the dry solids content of the web W is in the range of K1...K2, wherein K1 = ultimate dry solids content - 7 % and K2 = ultimate dry solids content + 3 %, and the temperature of the web at the steam boxes 64,65 is lower than 85 °C, preferably lower than 75 °C.

As comes out from the figure, the diameter D_{11} of the reversing rolls or cylinders 11 in the last dryer group R_{23} is larger than the diameter D of the reversing rolls or cylinders 11 in the preceding groups. In view of regulation of the tendency of curling, in the last dryer group R_{23}, the diameter ratio of the diameter D_{11} of the reversing cylinder 11 to the diameter D_0 of the drying cylinders 10 / cooling cylinders 61,63 has been chosen so that the web W is also cooled in this way on the face of the reversing cylinder 11 of a diameter larger than usual so as to intensify the effect of regulation of the curl. The diameter ratio D_0/D_{11} is 0.75...2.5, preferably 1...1.5.

Since attempts are made to cool the web by means of cylinders of a lower temperature placed in the end of the dryer section and possibly by using larger reversing cylinders, it is also advantageous to employ a wire circulation of their own on said cylinders. In this way the other, heatable cylinders and the long wire circulation cannot heat the wire and, thereby, the web in the end of the dryer section. In order to provide additional capacity, the wire can be cooled further, for example, by blowing of cold air.

Even though it is not illustrated in the figure, the dryer section is placed inside a hood, in a conventional way, for recovery of the moist air, to improve the energy economy, and to intensify the air-conditioning of the dryer section. In particular,

when a wire circulation of its own is employed in the end, it is preferable to isolate said area from the rest of the hood by means of a partition wall. By means of this solution, the wire is kept colder and both the energy efficiency and the operability of the air-conditioning of the dryer section are improved.

The applicant of patent has also noticed that, from the point of view of the ultimate properties of the paper, it is advantageous that said curl regulation operations are carried out when the web is supported, e.g., against the drying wire, as is shown in Figs. 1 and 2. The final result is also better when the web is subjected to a draw either in the machine direction or in the cross direction. In Fig. 2, the web is drawn between the last drying cylinder and the calender, i.e. the web is subjected to a tension in the machine direction when it is steam-treated/moistened by means of the device 65.

Fig. 3 is a schematic illustration of test results related to regulation of the curl of paper by means of water moistening and steam treatment. The Y axis represents the curl, and the X axis represents the test points 1 to 3. In the test point 1, one-sided drying has been used, in the test point 2 one-sided drying and steam-treatment, and in the test point 3 one-sided drying, water moistening and steam-treatment. When the sign of the curl is positive, the curling takes place towards the top side, and when the sign of the curl is negative, the curling takes place towards the bottom side. As is seen from the figure, a one-sidedly dried web curls intensively (20 units). Steam treatment alone at one stage reduces the curl substantially, but the web still curls in the original direction by about five units. When the web has been moistened slightly before steam treatment, the web curl direction can be even reversed.

Even though the invention is preferably applied in connection with the dryer section solution described in the exemplifying embodiment, the invention is by no means supposed to be strictly confined to said solution, but the invention can also be utilized in connection with conventional cylinder dryer concepts or while using drying other than cylinder drying, such as, for example, impingement drying.

Claims

1. A method in the dryer section of a paper or board machine for control of the curl of paper, in which method steam treatment and/or moistening of the paper web (W) is/are employed, **characterized** in that, in the method, the operations carried out in view of controlling the curl of the paper web (W) are carried out in a number of stages before the finishing device that works the web mechanically in a dry solids content range K1...K2 of the web (W), wherein K1 = ultimate dry solids content - 7 % and K2 = ultimate dry solids content + 3 %, and when the web (W) temperature is, during at least one stage, lower than 85 °C, preferably lower than 75 °C.

2. A method as claimed in claim 1, **characterized** in that, in the method, the paper web (W) is dried in a forward dryer section (D_1) in dryer groups ($R_0...R_n$) by means of drying cylinders (10), against whose heated faces the paper web (W) is pressed by means of the drying wire (15), after which the paper web (W) is passed from the forward dryer (D_1) into a finishing section (D_2), in which the paper web (W) is coated/surface-sized by means of a coating/surface-sizing equipment (20), the paper web (W) is dried in an after-dryer (30), after which the paper web (W) is calendered in a calender (40) and passed to a reeling station (50), in which the paper web is reeled into a machine reel (MR).

3. A method as claimed in claim 1 or 2, **characterized** in that, in the method, in the forward dryer section (D_1) the paper web (W) is dried from the side of its bottom face in dryer groups ($R_0...R_n$) that apply a normal single-wire draw.

4. A method as claimed in any of the claims 1 to 3, **characterized** in that in the after-dryer (30) the paper web (W) is dried in dryer groups (R_{21},R_{22},R_{23}) that apply a normal single-wire draw.

5. A method as claimed in any of the claims 1 to 4, **characterized** in that, in the method, in the last dryer group (R_{23}) in the dryer (30), a ratio of 0.75...2.5,

preferably 1...1.5, is used as the diameter ratio (D_0 : D_{11}) of the drying cylinders (10) to the reversing cylinders (11).

6. A method as claimed in any of the claims 1 to 5, **characterized** in that, in the method, at least as the last cylinder, preferably as the last two cylinders (61,63) in the last dryer group (R_{23}), cylinders are used whose temperature(s) can be regulated separately.

7. A method as claimed in claim 6, **characterized** in that, in the method, as the cylinders whose temperatures can be regulated separately, cylinders (61,63) are used which can be cooled.

8. A method as claimed in claim 6, **characterized** in that, in the method, in connection with the last cylinders (61,63), the web (W) is carried by means of a wire circulation of their own.

9. A method as claimed in claim 8, **characterized** in that, in the method, the last cylinders, which are provided with a wire circulation of their own, are separated from the rest of the hood of the dryer section by means of a partition wall placed in the hood.

10. A method as claimed in claim 8, **characterized** in that, in the method, the wire of the wire circulation is cooled.

11. A method as claimed in any of the claims 1 to 10, **characterized** in that, in the method, the regulation of the curl is carried out in the last dryer group in the dryer section so that the paper web (W) is moistened by means of a moistening device (62), after which the web (W) is passed along the cylinder face of the first cylinder (61) which can be cooled onto the following reversing cylinder (11), in connection with which the web (W) is steam-treated by means of a steam box (64) or moistened by means of a moistening device, after which the web (W) is passed along the face

of the cooled cylinder (63) past a steam box (65) or a moistening device to the calender (40).

12. A method as claimed in claim 11, **characterized** in that, in the method, the paper web (W) is dried to excessive dryness before regulation of the curl.

13. A method as claimed in claim 1, **characterized** in that, in the method, the paper web (W) is supported or kept under draw in the machine direction during the steam-treatment/moistening treatment.

14. A method as claimed in claim 1, **characterized** in that, in the method, the paper web (W) is subjected to a spreading effect during the steam-treatment/moistening treatment or directly after said treatment.

15. A paper or board machine, which comprises at least a headbox, a former, a press, and a dryer section, in which steam boxes or moistening devices are employed for control of the curl, **characterized** in that there are at least two of said curl regulation devices in view of achieving a regulation of the curl in a number of stages, and that the operations carried out in view of controlling the curl of the paper web (W) are carried out in a number of stages before the finishing device that works the web mechanically in a dry solids content range K1...K2 of the web (W), wherein K1 = ultimate dry solids content - 7 % and K2 = ultimate dry solids content + 3 %, and when the web (W) temperature is, during at least one stage, lower than 85 °C, preferably lower than 75 °C.

16. A paper or board machine as claimed in claim 15, **characterized** in that the dryer section comprises a forward dryer section (D_1) and a finishing section (D_2), which finishing section (D_2) comprises a coating/surface-sizing equipment (20), an after-dryer (30), a calender (40), and a reeling station (50).

17. A paper or board machine as claimed in claim 15 or 16, **characterized** in that the forward dryer section (D_1) comprises dryer groups ($R_0 \ldots R_6$) which apply a normal single-wire draw.

18. A paper or board machine as claimed in any of the claims 15 to 17, **characterized** in that the dryer groups (R_{21},R_{22},R_{23}) in the after-dryer (30) are dryer groups which apply a normal single-wire draw.

19. A paper or board machine as claimed in any of the claims 15 to 18, **characterized** in that in the last dryer group in the after-dryer (30), the diameter ratio (D_0 : D_{11}) of the drying cylinders (10) to the reversing cylinders (11) is 0.75...2.5, preferably 1...1.5.

20. A paper or board machine as claimed in any of the claims 15 to 19, **characterized** in that at least the last cylinder, preferably the last two cylinders (61,63) in the last dryer group (R_{23}) in the after-dryer (30) are cylinders whose temperatures are separately adjustable.

21. A paper or board machine as claimed in claim 20, **characterized** in that the cylinders whose temperatures are separately adjustable are cylinders (61,63) which can be cooled.

22. A paper or board machine as claimed in claim 20, **characterized** in that the last cylinders (61,63) have a wire circulation of their own.

23. A paper or board machine as claimed in claim 22, **characterized** in that the hood of the dryer section includes a partition wall so as to separate the wire circulation of the last cylinders (61,63) from the rest of the hood of the dryer section.

24. A paper or board machine as claimed in claim 22, **characterized** in that the wire of the wire circulation of the last cylinders (61,63) can be cooled.

25. A paper or board machine as claimed in any of the claims 15 to 24, **characterized** in that the curl regulation devices are placed in the last dryer group in the dryer section, that a moistening device (62) is placed before the first cylinder (61) that can be cooled in order to moisten the web (W), that a steam box (64) or a moistening device is placed before the second cylinder (63) that can be cooled, and that a steam box (65) or a moistening device is placed before the transfer of the web (W) to the calender (40).

26. A paper or board machine as claimed in claim 25, **characterized** in that the web (W) is fitted to be dried to excessive dryness before the curl regulation devices.

27. A paper or board machine as claimed in claim 15, **characterized** in that in connection with the steam-treatment/moistening treatment the paper web (W) is supported or subjected to a draw in the machine direction.

28. A paper or board machine as claimed in claim 15, **characterized** in that a web (W) spreading device is fitted in connection with, or directly after, the steam-treatment/moistening devices.

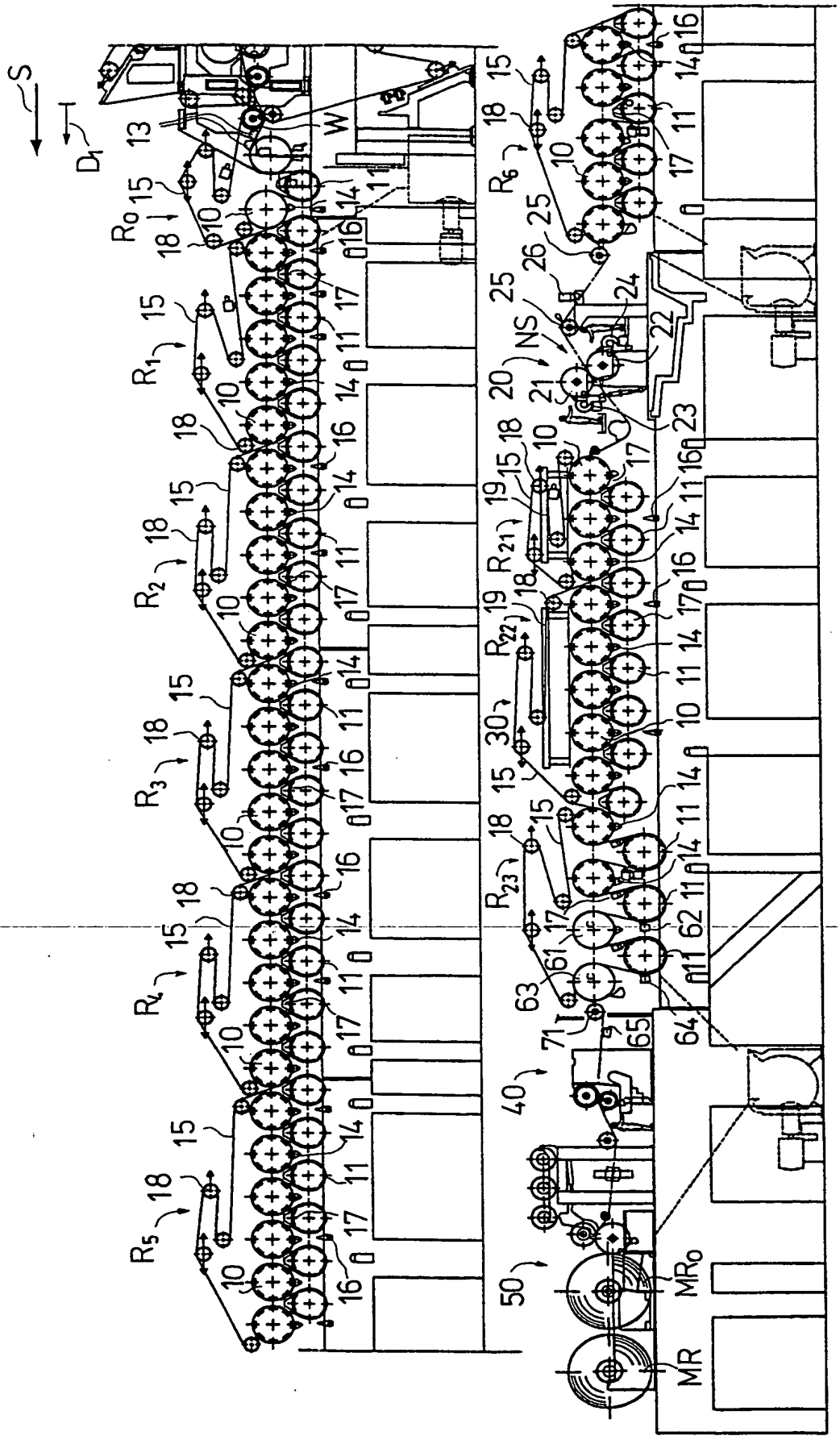
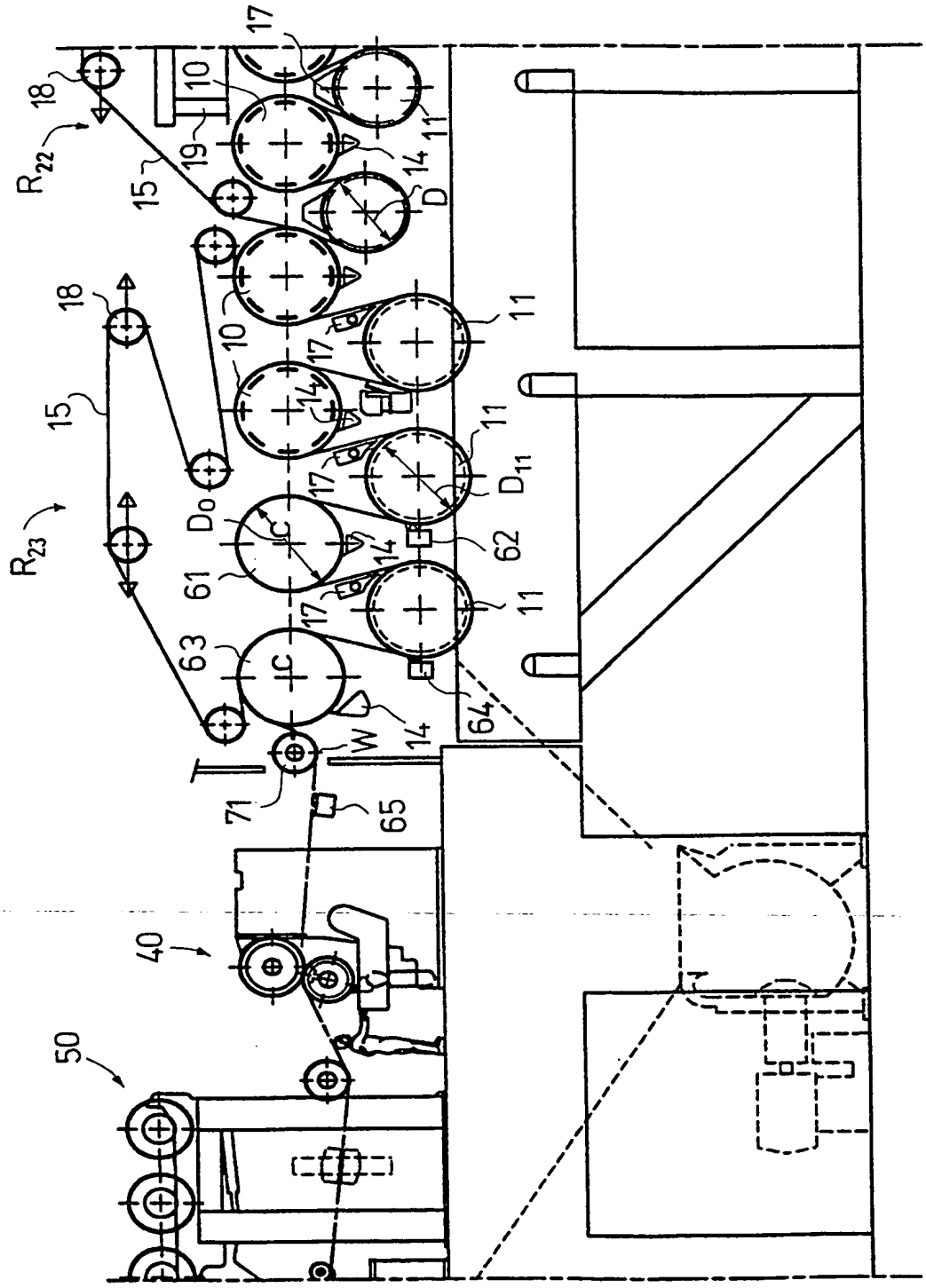


FIG. 1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10
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11
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D
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R_{22}
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50

FIG. 2

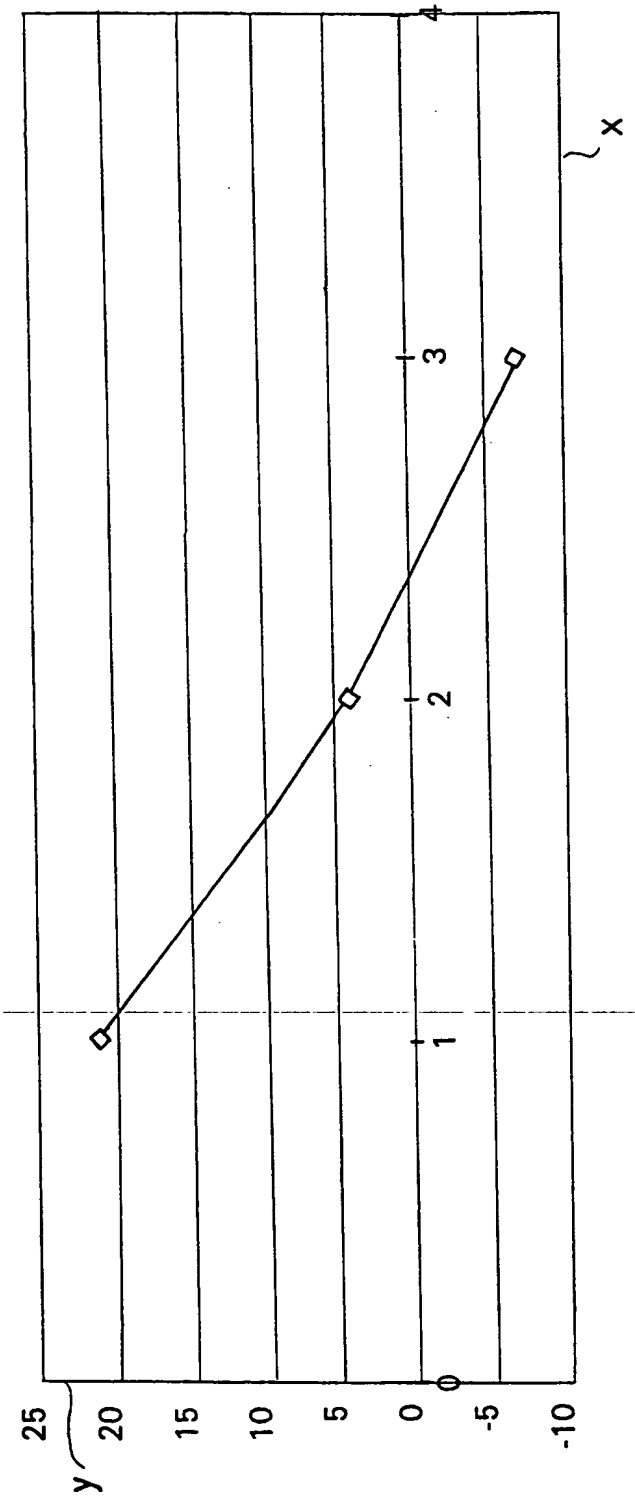

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/00253

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: D21F 5/04
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: D21F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5557860 A (KOTITSCHKE ET AL), 24 Sept 1996 (24.09.96), column 4, line 38 - column 5, line 32, figures 1-4, abstract --	1-28
X	US 5416980 A (ILVESPÄÄ), 23 May 1995 (23.05.95), column 7, line 31 - line 45, abstract --	1-28
X	EP 0726353 A2 (VALMET CORPORATION), 14 August 1996 (14.08.96), column 20, line 45 - column 21, line 15, figure 11A, abstract -- --------	1-28

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 June 1998	29 -06- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Björn Salén Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

Information on patent family members

09/06/98

International application No.
PCT/FI 98/00253

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